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LATE TERTIARY MOLLUSKS FROM THE LOWER COLORADO RIVER VALLEY

By

Dwight W. Taylor[1]

Abstract. In the Colorado River Valley, Arizona and California, the late Miocene Bouse Formation records a brackish to marine embayment that extended northward from the head of the Gulf of California. A brackish-water snail from this unit is described as new; it is of interest because its nearest relative lives in the western Atlantic Ocean. An assemblage of Miocene freshwater mollusks from calcareous facies of the Muddy Creek Formation, Nevada, support correlation with the Bouse Formation.

INTRODUCTION

In late Miocene time a brackish to marine embayment extended up the Colorado River valley, Arizona and California, from the head of the Gulf of California. Its sedimentary record, the Bouse Formation, has been described by Metzger and Loeltz (1973) and Metzger et al. (1973). The benthic fauna is sparse, consisting of ostracodes, Foraminifera, and marine, brackish-water, and freshwater mollusks (P.B. Smith, 1970; Metzger et al., 1973). The new species of *Batillaria* (a brackish-water snail) described herein is of interest because its closest relative lives in the Gulf of Mexico and Caribbean Sea.

North of the northernmost marine species in the Bouse Formation, in the vicinity of Lake Havasu, two localities have yielded sparse freshwater mollusks. *Valvata* cf. *V. idahoensis* is found also in the calcareous facies of the Muddy Creek Formation, southern Nevada. The species is known otherwise only from the late Miocene Salt Lake Group in southeastern Idaho, prompting speculation of former drainage southward from Idaho across what is now the Great Basin in Utah.

Few species are known from stratigraphically above and below the Bouse Formation, but they consist of different assemblages, and help to bracket that unit as late Miocene. All mollusks from the Muddy Creek Formation, believed to be correlative with the Bouse, are freshwater. They conflict with interpretations that part of the Muddy Creek was deposited in the head of the Bouse estuary.

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Description of New Species
Family Potamididae
Genus *Batillaria* Benson, 1842
Subgenus *Lampanella* Mörch, 1876
Batillaria californica Taylor, n. sp.
Fig. 1a-d, Table 1

Bittium: Blanchard 1913:39; Ross 1922:190; Taylor 1966:92.
Melania or *Goniobasis:* Ross 1922: 189-190; Taylor 1966: 91-92.
Cerithid: Wilson 1931: 567; Taylor 1966: 92.
Batillaria: Metzger 1969: D133; Smith 1970: 1414, 1416; Metzger et al. 1973: G18.

Diagnosis: A species of *Batillaria* (*Lampanella*) distinguished by relatively small size and lack of nodulose or strong spiral sculpture on the body whorl. It has the flat-sided spire, oblique channel of aperture, relatively heavy shell and columellar callus of *B. minima,* combined with the fine spiral sculpture of *B. mutata.*

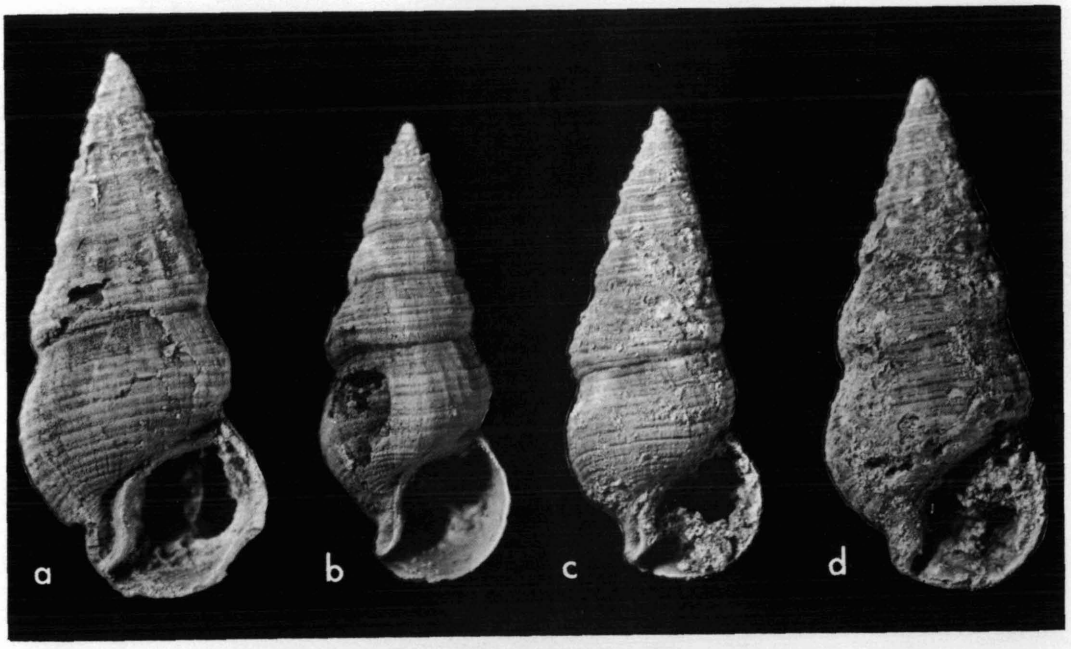

FIG. 1— *Batillaria californica* Taylor, n. sp. a, paratype, USNM 305209, length 7.4 mm; b, holotype, USNM 305208, length 6.2 mm; c, paratype, USNM 305210, length 6.2 mm; d, paratype, USNM 305211, length 6.9 mm.

Description: Shell small, slender, pyramidal, with 10-11 flat whorls; body whorl regularly rounded at periphery; low rounded riblets may be present above periphery. Sculpture of spiral threads and cords that override weak axial riblets; on last whorls of spire and above periphery of body-whorl 9-11 spiral cords of about equal height, separated by interspaces that may be as wide as the cords; interspaces with 1-5 fine spiral threads; base, below periphery, with 8-10 spiral cords, their strength, spacing and intercalary threads as above the periphery. At 3-4 whorls the

sculpture consists of 3-4 spiral cords, and fine spiral threads; the cords gradually becoming waved and more numerous as they override low axial riblets; on the middle part of the spire the cords may be strengthened as they pass over the riblets to form spirally elongate tubercles. Growth striae very fine. Aperture triangular with rounded sides; outer nearly vertical and lower nearly horizontal, sides connected by a broad, even curve; columellar margin concave; columella short and broad, vertical, abruptly truncate below, separated from base of outer lip by a deep but short, oblique channel; lip simple, scarcely produced basally, thin or slightly thickened; aperture smooth; callus of columellar margin separated by a notch and narrow groove from the outer lip. (The description follows closely that by Bequaert, 1942, for *B. minima* to facilitate comparison).

Comparisons. Batillaria mutata (Pilsbry and Vanatta, 1902) of the Galapagos Islands is distinct from *B. californica* by its larger size, thinner shell texture, more convex whorls and deeper suture, more prominent and wider prosocline riblets, nodulose sculpture below the suture, and shallow, wide, apertural notch. The two are similar in having fine spiral sculpture. (Comparison is based on syntypes, California Academy of Sciences Department of Geology Type Collection 8022-8024, and Stanford University 6224, as well as the original description).

Batillaria minima (Gmelin, 1790) of the western Atlantic is distinct by its larger size, flatter whorls and more weakly impressed suture, stronger riblets, strong spiral sculpture with elongate nodes on the riblets, and anterior channel of aperture more nearly normal to the columella. (Comparison is based on series in the California Academy of Sciences, and description by Bequaert, 1942).

TABLE 1 — Measurements of *Batillaria californica.*

	Length	Width (body whorl)	Whorls
Type, Fig. 1b	6.2 mm	2.8	10 1/4
Paratype, Fig. 1a	7.4	3.2	10 3/4
Paratype, Fig. 1c	6.2	2.6	10
Paratype, Fig. 1d	6.9	3.0	9+
Largest seen	8.0+	3.6	10+

Type locality: U.S. Geological Survey locality M3091. Imperial County, California, 5600 ft W, 2800 ft N, in irregular sec. 20, T. 10 S., R. 21 E. Roadside exposures of basal limestone in Bouse Formation; D.G. Metzger, March 1967 (HA-2-21-16) (original collection including type and paratypes); D.G. Metzger and D.W. Taylor, March 15, 1968. Holotype U.S. National Museum of Natural History 305208, paratypes USNM 305209-305211.

Associated fossils: Silicified fossils in limestone were removed by maceration in weak acid. *Batillaria* was the most common form. Also present in numbers were stems and zygospores of Characean algae and small crabs represented most conspicuously by chelae. Less abundant were the marine mollusks ?*Barleeia, Diplodonta,* and *Halodakra,* and barnacles. Foraminifera (unstudied) were found after preparation of the publication by Smith (1970).

Occurrence and associates of *Batillaria californica* are in agreement with the habitat of its near relative: "*B. minima* is often found in abundance in shallow brackish water where it lives in the mud of the intertidal zone" (Bequaert, 1942).

Other occurrences: Material of *Batillaria californica* has been examined from three other localities:

USGS M3089. Yuma County, Arizona. Buckskin Mts., 1200 ft W, 3300 ft N, sec. 34, T. 10 N., R. 19 W.; D.G. Metzger, March 1967 (EU-1-64-21).

USGS M3090. Yuma County, Arizona. Osborne Wash, 1500 ft W, 700 ft N, sec. 1, T. 9 N., R. 19 W.; D.G. Metzger, March 1967 (EU-1-64-22).

Yuma County, Arizona. Trigo Mts., SW of Cibola, 1900 ft W, 450 ft N, sec. 17, T. 2 S., R. 23 W.; D.G. Metzger, 1965 (Col. 1-98-1).

A collection from a fourth locality was at one time in USGS collections but has been lost. W.P. Woodring identified *Batillaria* in a report to D.H. Kupfer, August 8, 1953.

USGS 18414. Imperial County, California. Northeast corner of Palo Verde Mts., south bank of small gully, about 400 ft N 37° W from USCGS monument H-134; D.H. Kupfer, 1953 (533-31A).

Two other American fossil species of *Batillaria* have been described: *B. transecta* (Dall, 1890) and *B. advena* (Palmer, 1953).

Batillaria transecta (Dall, 1890-1903: 189, 287; 1915:91; Mansfield, 1937: 154) was described as a member of the subgenus *Lampanella* but not differentiated from *B. minima*. It is from the Miocene Tampa limestone of northern Florida. Features of the species much like *B. minima* are in particular the flat-sided spire with four spiral cords on each whorl, axial riblets, and short canal nearly perpendicular to the columella. In view of the considerable variation in *B. minima* cited by Bequaert (1942), the validity of *B. transecta* seems doubtful.

Batillaria advena Palmer (1953) may not belong to the genus; at any rate its strong axial sculpture is markedly different from that of *B. californica*.

Search for relationships within the genus, and preparation of a distribution map (Fig. 2), led to a review of the classification published by Wenz (1938-1944). One of the living subgenera he cited, *Batillariella,* has subsequently been transferred from Potamididae to Cerithiidae by Macpherson and Gabriel (1962). *Velacumantus* and *Zeacumantus* (both misspelled by Wenz) are generally ranked as separate genera in current works. Neither overlaps the range of *Batillaria* s.s. The type species of *Batillaria, B. zonalis* (Bruguière), is cited as an Australian species by Wenz, but no recent Australian work recognizes it.

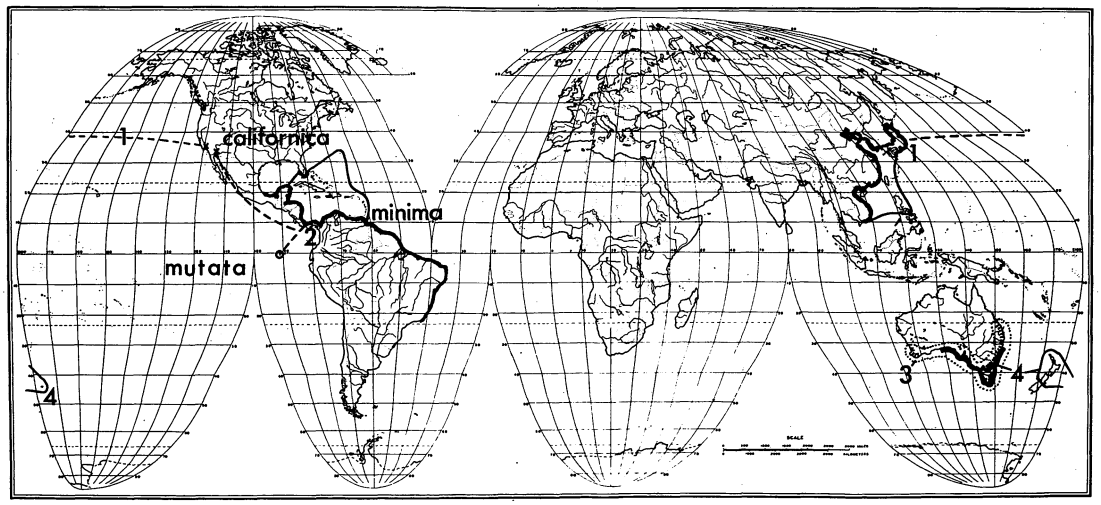

FIG. 2— Distribution of *Batillaria* and related genera. 1, *Batillaria s.s.*; 2, *Batillaria* (*Lampanella*); 3, *Velacumantus* (after Ewers, 1967); 4, *Zeacumantus* (after Cotton, 1959; Macpherson and Gabriel, 1962; Powell, 1976). Solid lines, modern range; x, fossil.

Distribution of *Batillaria* (*Lampanella*) is from Bequaert (1942), Keen (1971), and Rios (1975). The last review of *Batillaria* (*s.s.*) is by Kobelt (1888-1898) and both taxonomy and distribution in that work are in need of revision. The generalized range mapped (Fig. 2) is from southern Hokkaido, Japan (Habe, 1964) to the Mekong River, Viet Nam (Fischer and Dautzenberg, 1904), including a Philippine locality (Faustino, 1928); Fischer (1973) does not list the genus from Cambodia.

In Tertiary times there was no isthmus of Panama, and a similar fauna of marine mollusks ranged widely through the present Caribbean Sea and the central eastern Pacific Ocean. Descendants of that fauna have survived unequally on either side of middle America. Those living only in the Pacific are paciphile species; only in the Caribbean, caribphiles (Woodring, 1966). *Batillaria californica* from the Miocene Bouse Formation, Arizona-California, is the northernmost element of that former Tertiary Caribbean faunal province. Its closest relative, *B. minima,* lives in the Gulf of Mexico and Caribbean Sea area, hence now can be termed a caribphile species. These two species are more like each other than *B. mutata,* living in the Galapagos; the three make up the subgenus *Lampanella.*

In California a second fossil species of *Batillaria* is known from the Miocene of the San Joaquin Valley: *B. ocoyana.* That species belongs to *Batillaria* s.s., living from northern Japan to southern Viet Nam. Several other brackish-water fossil mollusks have similar distributions: those from southern California are related to species in the Gulf of Mexico, those from areas farther north are related to species of eastern Asia (Table 2).

TABLE 2 — Geographic relationships of some brackish-water mollusks in California

	Living relative	Reference
Fossil, S California		
Batillaria californica, n. sp.	*B. minima,* Gulf and Caribbean	This paper
Rangia lecontei (Conrad)	*R. cuneata* (Gray), Gulf of Mexico	Dall, 1894; Taylor, 1966
Fossil, central California to Washington		
Batillaria ocoyana (Anderson and Martin)	*B.* spp., E. Asia	Addicott, 1970
Batissa sp.	*B.* spp., E Asia	MacNeil, 1965
Corbicula spp.	*Corbicula,* E Asia	Henderson, 1935

AGE, ENVIRONMENT, AND CORRELATION OF BOUSE AND MUDDY CREEK FORMATIONS

The sparse assemblages of freshwater mollusks from Bouse and Muddy Creek Formations (Table 3) include only one form in common, *Valvata* cf. *V. idahoensis.* That is a distinctive species of the genus, bearing multiple spiral cords on the shell, and known elsewhere only from the late Miocene Salt Lake Group of southeastern Idaho (Taylor and Smith, 1981). These data support the late Miocene age, and the correlation of Bouse and Muddy Creek Formations, by McKee et al. (1967).

Living species of *Valvata* are restricted to perennial fresh water. The unexpected relationship of the Muddy Creek fossils to a species from southeastern Idaho prompts speculation that there was drainage southward across what is now the Bonneville basin into the lower Colorado River valley. The fossils from the Lake Havasu area (localities 20226, 20227 in Table 3) indicate a perennial freshwater habitat consistent with interpretation of drainage southward (Metzger et al., 1973: G13).

The other two forms identified specifically are still living in the region. *"Fluminicola" avernalis* is restricted to a group of warm springs at the head of Muddy River, tributary to the Virgin River (Gregg, 1941). It indicates a habitat of perennial oxygenated fresh water, most likely spring-fed streams. Whether the fossils of the Muddy Creek Formation might have been transported from such a habitat, or whether they indicate immediately local occurrence of such a situation is not known.

Anodonta californiensis is a freshwater mussel living in Arizona, California and states to the north. It was originally described from one of the distributaries of the Colorado River in what is now the Imperial Valley, California. It is found in perennial creeks, rivers, and lakes.

All of the mollusks from the Muddy Creek and Bouse Formations listed in Table 3 are strictly freshwater. There is no possibility they lived in brackish, marine, or hypersaline conditions, an environment postulated by some (Blair and Armstrong, 1979; Blair and Bradbury, 1979; Cornell 1979) for the embayment from the Gulf of California.

TABLE 3 — Freshwater mollusks from Muddy Creek and Bouse Formations, Arizona, California, Nevada

	USGS Cenozoic locality			
	20226	20227	22250	22252
Gastropoda				
Valvata cf. *V. idahoensis* Taylor	x	x		x
"Fluminicola" avernalis Pilsbry			?	x
Lymnaeidae		x		x
Physa	x			x
Pelecypoda				
Anodonta californiensis Lea		x		
Musculium	?			

20226: Mohave Co., Ariz. East side of Lake Havasu, 3/4 mi N, 1/2 mi E of Car Body Landing; Hadley and Wiese, 1941.

20227: San Bernardino Co., Calif. By power line road near where it crosses the west line of T.4 N., R. 25 E., 5 mi S of Needles Boat Landing on Lake Havasu; C.B. Hunt et al., 1941. Mapped as Tertiary volcanics, undivided, on Geologic Map of California, Needles sheet (1963). Locality 20227 is referable to the Bouse formation (D.G. Metzger, personal communication).

22250: Clark Co., Nev. E 1/2 Sec. 35 and W 1/2 Sec. 36, T. 19 S., R. 63 E.; Muddy Creek Formation, carbonate facies; C. R. Longwell, 1960.

22252: Clark Co., Nev. SW1/4 Sec. 26, T. 19 S., R. 63 E.; Muddy Creek Formation, calcareous facies; W.H. Hays, 1958.

A rich variety of potassium-argon dates is available pertaining to the Bouse and Muddy Creek Formations.

A tuff bed in the basal limestone of the Bouse Formation was first given a minimum date of 3.02 ± 1.15 million years (Metzger, 1969: 133). A second analysis of non-devitrified portions yielded a date of 8.1 ± 0.5 m. y. Later, four analyses of three samples were dated as 5.47 ± 0.20 m. y. (Damon et al., 1978).

Overlying Muddy Creek Formation in the Lake Mead area, but below the calcareous facies (Hualapai Limestone Member) is a basalt on Fortification Hill. This has been dated at 10.6 ± 1.1 m. y., 10. 9 ± 1.1 m. y., and lastly as 5.88 ± 0.18 m. y. (Blair and Armstrong, 1979; Damon et al., 1978).

The Hualapai Limestone Member, above the basalt mentioned, has been dated at 8.66 ± 2.2 m. y. (Blair and Armstrong, 1979).

FOSSIL MOLLUSKS OLDER THAN BOUSE FORMATION

Only one collection of mollusks is known from the lower Colorado River valley that is stratigraphically beneath the Bouse Formation. It includes a single species, the freshwater snail *Bulimnea,* from the following locality in the northern Sacramento Mountains:

TABLE 4 — Miocene freshwater mollusks from Barstow Formation and Argus Range, southeastern California

	Barstow	Argus
Lymnaea lawsoni (Hannibal)	x	x
Bulimnea sp.	x	x
Pseudosuccinea columella (Say)	x	
Planorbella (*Pierosoma*) sp.	x	
Planorbula mojavensis (Hannibal)	x	
Menetus? micromphalus Taylor	x	x
Gonidea sp.	x	
Sphaerium cf. *S. lavernense* Herrington		x
Pisidium ref. *P. casertanum* (Poli)	x	

Barstow Formation list revised from Taylor (1954), with additions by later collecting. Argus Range list from California Academy of Sciences locality 37283: Inyo Co., California. East side of Argus Range, 1/2 mile west of Onyx mine; collected by G.D. Hanna, C.W. Chesterman, Frank Weidenbenner, 1961-62.

U.S. Geological Survey Cenozoic locality 22064. San Bernardino Co., California. Bannock quadrangle (1956) 1: 62500. SE 1/4 NW 1/4 sec. 22, T. 8 N., R. 21 E. Brown-weathering dark gray carbonate rock. Fossils from 1-inch bed on west-facing flank of outcrop on east side of road where road turns up out of wash. W.L. Coonrad, collector, 1960.

This locality is a few miles from a fossil mammal occurrence (section 4 of the same township) dated as probably middle Miocene in age (Metzger and Loeltz 1973: 8). Although the stratigraphic relationship of the fossil snails and mammals is unknown, both evidently are from the "bedrock," that is, beneath fanglomerate older than Bouse Formation, and separated from the fanglomerate by a major unconformity and episode of severe deformation (Metzger and Loeltz 1973: 9).

Elsewhere in the Mohave Desert *Bulimnea* is known from the middle Miocene (Barstovian) Barstow Formation (Taylor 1954) and latest Miocene (Hemphillian) Bedrock Springs Formation (G.I. Smith 1964), both dated by fossil mammals. Other localities in southern California are Barstovian, in the Caliente Formation (James 1963; dated by fossil mammals) and in the Argus Range (Table 4, associated with a Barstow-type molluscan fauna).

No late Miocene (Clarendonian) freshwater mollusks are surely known from southeastern California. The available data do show a lack of overlap between the middle Miocene Barstow-

type fauna and the Bouse and Muddy Creek faunas (Tables 3, 4), so far as identifiable to genus. Thus on molluscan evidence the Bouse and Muddy Creek assemblages are late to latest Miocene, consistent with known stratigraphy. A latest Miocene (Hemphillian, about 5.5 to 9 million years) age is consistent with an appropriate selection of potassium-argon dates. An older Clarendonian age can be supported with a different selection of dates.

FOSSIL MOLLUSKS YOUNGER THAN BOUSE FORMATION

Only one collection of mollusks is known from the lower Colorado River valley that is stratigraphically above the Bouse Formation. It included four species, all extant: the freshwater snails *Bakerilymnaea cubensis* (Pfeiffer), *Physa virgata* Gould, and the land snails *Vertigo ovata* Say and a species of *Succinea*? The locality is as follows:

Mohave Co., Arizona. North side of Sacramento Wash, 800 ft. west, 2400 ft. north of southeast corner sec. 26, T. 16 N., R. 21 W. Yellowish-gray limonite-streaked silt bed, 1-2 feet thick, flat-lying. D.G. Metzger, collector, 1968.

This locality is within unit B of the older alluvium of the Colorado River as described by Metzger and Loeltz (1973: 13-14). The sparse assemblage of freshwater mollusks consists of species living locally, and does not refine the Pliocene-Pleistocene age assignment derived from stratigraphic evidence. Both are found in Pliocene deposits of the San Pedro River valley, southern Arizona (Taylor, 1966).

EXTENT OF BOUSE ESTUARY

Blair and Armstrong (1979) concluded that the former Bouse embayment from the Gulf of California extended as far as the Grand Wash Cliffs of northwestern Arizona. The Hualapai Limestone Member of the Muddy Creek Formation they believed was deposited in an estuary at the north end of the former gulf or in an embayment. A satisfactory resolution of various interpretations will require more fossils and especially more field studies.

The fossil mollusks from the Muddy Creek Formation are freshwater species that could not have lived in brackish or marine waters. The one species known from several localities, *"Fluminicola" avernalis* Pilsbry, has a small shell less than 5 mm long. Small marine or brackish-water species would be expected if the Muddy Creek Formation, even only the Hualapai Limestone Member, were deposited at the head of an ancestral Gulf of California.

Striking features of the Muddy Creek Formation that have impressed all previous workers are (1) the large volume of chemical precipitates, and (2) the absence of evidence of a through-flowing Colorado River from its present Grand Canyon course. Longwell (1936) suggested much of the carbonate in the Muddy Creek formation was derived from discharge of springs. This is consistent with the molluscan fossils. *"Fluminicola" avernalis* now lives in springs at the head of the Muddy River, a tributary of the Virgin River. Spring-fed sources of carbonate in the Muddy Creek Formation would also be consistent with the suggestion by Hunt (1969) that flow of the Colorado River was by percolation through limestone of the Colorado Plateau before formation of the lower Grand Canyon. The molluscan evidence from the Bouse and Muddy Creek Formations suggests that there was no ancestral Colorado River tributary to the Bouse embayment, only northern tributaries such as the Virgin and White Rivers, if indeed those streams were in existence. The present interpretation differs from those by Lucchita (1972, 1979)

in that no ancestral Colorado is postulated as tributary to the Bouse employment, and the Hualapai member of the Muddy Creek Formation need not have been deposited near sealevel.

Other interpretations of paleogeography and the development of drainage in the lower Colorado River area depend on evidence from outside the region. Taylor (in press) has summarized drainage evolution as inferred from freshwater mollusks.

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